Environment and Well-being Before and Following Smoking Ban in Office Buildings

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ABSTRACT

The purpose of this study was to compare the well-being, salivary cotinine levels and environmental characteristics of office building workers and their workplace before and after the introduction of a smoking ban. The results showed that one year following the ban, there was an ambiguous change in symptom reporting, a trend towards reduced salivary cotinine levels, and an improvement in measured but not in perceived environmental quality.

ABRÉGÉ

Le but de cette étude était de comparer le bien-être, les niveaux de cotinine salivaire et les caractéristiques environnementales des personnes qui travaillent dans des bureaux et de leur lieu de travail en général avant et après l'introduction de l'interdiction de fumer. Les résultats ont permis de constater, un an après l'interdiction, un changement ambigü relatif aux symptômes rapportés, une tendance à la réduction des niveaux de cotinine salivaire et une amélioration mesurable mais non perceptible de la qualité de l'environnement.

Environmental tobacco smoke (ETS) is suspected of contributing to building-related adverse health effects.[1] This is plausible in view of its odour and irritant effects.[2]

There have been several studies of the effects of ETS on office building workers. One showed that discomfort and decreased well-being did not vary with whether the work stations of staff members were located in smoking or in non-smoking areas.[3] Another demonstrated that a building where smoking was permitted had higher particulate levels, and both less favourable perceptions of the work environment and a higher prevalence of mental fatigue among the employees, than in a no-smoking building.[4] In two other studies, a smoking ban was followed by a reduction in environmental nicotine and particulate levels,[5,6] and a perception of improved air quality.[5]

The purpose of the following study was to further explore the possible adverse effects of ETS in office buildings, before and after the introduction of a smoking ban.

METHODS

The study was performed in three public sector, non-problem buildings. The pre-smoking ban survey was carried out in March 1989 and the post-ban survey in March 1990. The ban came into effect on April 1, 1989.

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The indoor environment was monitored in eight to 12 sectors of each floor, on a morning and afternoon during the same period as the employees were evaluated. The variables measured were temperature and humidity (Jenway micropsychrometer); particulates (Ham aerosol meter); carbon monoxide (International Scientific electrochemical meter); and carbon dioxide (ADC infrared analyzer). The concentration of ionizable substances was estimated using an HNU photoionization detector calibrated against an aliphatic hydrocarbon mixture (isoparaffin); volatile organic compounds are the most prevalent air pollutants in office building air detected by this method.

The study procedures were approved by an ethics committee of the Office of Research Administration of the University of Toronto. The estimated participation rate was about 20% of those employees who received an information package that was distributed in the buildings. Considerations of bias are dealt with in the Results and Discussion sections and in Table VI.

The questionnaire collected demographic information, details of smoking and ETS exposure, the level of satisfaction with eight features of the work environment, and the presence or absence of 15 symptoms and whether they occurred at work and/or at home. Other details of well-being included illness days, doctor visits and medication use during the previous year.

The participants also maintained a diary of nine of the questionnaire symptoms in the mornings and afternoons of seven consecutive days.

Salivary cotinine was assayed using an enzyme-linked, double antibody method[7]

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TABLE I
Characteristics of Subjects (N=137)

		1989	1990	p[a]
Age Yr		41.6	42.6	n.d
Female		60.6%	60.6%	n.d
Smoke	Never	21.5%	39.3%	
	Never + Passive	35.6%	17.8%	
	Ex	10.4%	23.0%	0.0001
	Ex + Passive	20.0%	7.4%	
	Current	12.6%	12.6%	
Cig/Day Smoked n=13[a]		20.7	18.5	.
Other Cig/Day	Work[c]	6.0	0.1	0.0001
	Home	2.7	1.6	0.03
	Elsewhere	2.2	1.8	.
No. Colds/Yr[d]		1.9	1.8	.
Illness Days		4.4	4.5	.
Physician Visits/Yr		3.3	3.1	.
Take Medications		21.1%	24.1%	.

a The statistical procedures utilized were paired t tests and paired categorical data analysis (catmod); p values are shown only when equal to or less than 0.05.
b Average number of cigarettes smoked per day is given for subjects who were current smokers in both surveys.
c Average number of cigarettes smoked per day by others in vicinity of subject while at work.
d Number of colds, illness days, physician visits and use of medications apply to the preceding year.

TABLE II
Symptom Frequencies (N=137)

		1989	1990	p[a]
Cough	Yes[b]	14.6%	12.4%	.
Dizzy	Yes	18.2%	10.9%	.
Eye Irritation	Yes	44.5%	37.2%	.
	Home	13.8%	14.6%	.
	Work	43.8%	34.3%	0.02
Headache	Yes	35.8%	24.1%	0.007
	Home	9.5%	10.2%	.
	Work	33.6%	24.1%	0.01
Nasal Irritation	Yes	61.3%	53.3%	.
Skin Problem	Yes	46.7%	42.3%	.
Sleepy	Yes	51.1%	38.7%	.
Short of Breath	Yes	11.6%	10.9%	.
Sputum	Yes	7.2%	10.2%	.
Stomach Problem	Yes	15.3%	12.4%	.
Stress	Yes	53.2%	45.2%	.
Throat Irritation	Yes	34.3%	29.2%	.
Tire	Yes	31.4%	30.7%	.
SUM SYMPT	Yes[c]	4.3	3.6	0.0006
	Home	1.9	1.7	.
	Work	4.0	3.5	0.03
DIARY SUM	Wkend	1.0	1.4	.
	Wkda[c]	1.6	1.7	.

a The statistical procedures utilized were paired t tests and the McNemar test of paired proportions; p values are shown only when equal to or less than 0.05.
b The frequencies listed for a given symptom derived from the questionnaire, represent the percentage of subjects who answered affirmatively to a symptom being present, and who reported that the symptom occurred respectively at home, or at work. Only the frequency for the yes variable is shown when there is no significant change in a given symptom between the two years in the yes, home or work variable. The diary results are shown only as the aggregate variable for weekend days and work days.
c SUM SYMPT is based on the questionnaire and represents average number of symptoms per subject respectively reported yes, at home or at work.
DIARY SUM expresses the diary results as average sum of proportions of half-days per subject during which all symptoms are reported on weekend days or work days.

TABLE III
Salivary Cotinine (N=137)*

		1989	1990
Mean ng/ml		6.54	4.98
Minimum Value = 0		72.3%	81.8%
Minimum >0 ng/ml		0.5	0.2
Maximum ng/ml		96.0	80.5
By Smoke	Non	0.05	0.21
	No+Passive	0.29	0.04
	Ex	4.79	1.94
	Ex+Passive	3.17	0.0
	Current	42.62	31.62

* Paired t tests were utilized to compare the means across the two years for the total group and the smoking category subsets. There were no significant differences.

The principal reagents (monoclonal antibody and poly-L-lysine bound cotinine) were generously provided by John J. Langone, PhD, Baylor College of Medicine, Houston, Texas.

The statistical analysis was performed using SAS.

RESULTS

The following results are based on 137 workers who participated in both surveys, out of the starting population of 179 subjects. The percentage of current smokers is unchanged between the two surveys, but there is a significant decrease in the proportion who report exposure to ETS, explained mainly by a reduction in exposure at work (Table I).

There is a significant decrease in several symptom variables between the questionnaires of the first and second surveys, but not in the diaries (Table II). These findings are similar whether based on the total population, only those who completed the diaries, or only those who did not smoke.

The mean cotinine level is 6.54 ng/ml in the first survey and 4.98 ng/ml in the second, but this change is not statistically significant even when analyzed using the Wilcoxon sign rank test (Table III). The salivary cotinine levels are positively associated with current smoking ($r = 0.57$; $p = 0.0001$); with the number of smoked cigarettes to which the subjects reported being passively exposed at work ($r = 0.25$; $p = 0.003$), at home ($r = 0.22$; $p = 0.009$) or elsewhere ($r = 0.26$; $p = 0.005$); and with the measured level of exposure to particulates at work ($r = 0.22$; $p = 0.01$). Between

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the two surveys, there is a high correlation of the salivary cotinine level within subjects (r=0.7; p=0.0001). At the second survey, significant correlations with salivary cotinine are seen only with current smoking and number of smoked cigarettes to which the subjects are exposed at home or elsewhere.

The level of light, glare and noise is considered to be satisfactory by a majority of workers at the first survey, and that of air movement and freshness unsatisfactory (Table IV). The perception of humidity, odour and temperature are approximately balanced between favourable and unfavourable. At the second survey, there is a significant change only in the perception of temperature (Table IV). Perceptions about the environment are not associated with smoking status at either survey.

Generally, the temperature, CO, CO_2 and particulates levels are within accepted levels (Table V).[15] The humidity levels are low. The mean level of ionizable substances (likely volatile organic compounds) is at the upper end of the accepted range.[16] There is a significant reduction in ionizable substances, temperature and carbon dioxide at the second survey (Table V).

A comparison is made between the 1989 characteristics of those subjects who participated in both surveys and those who were in the first survey but not in the second (Table VII); and also between the 1990 characteristics of those subjects who participated in both surveys, and an additional group of 322 subjects representing 50% of the workers from the same buildings who did not participate in the 1989 survey but agreed to complete the questionnaire in 1990 (Table VI). Both comparisons demonstrate several significant differences between participants and non-participants, suggesting that the study group could yield an underestimate of the true level of building-related discomfort.

TABLE IV
Environmental Perceptions (N=137)

		1989	1990	p*
Perceived Air Movement	Low	56.9%	57.7%	
	OK	37.2%	33.6%	
	High	5.8%	8.8%	
Fresh Air	Low	74.5%	70.8%	
	OK	25.6%	28.5%	
	High	0.0	0.7%	
Glare	No	63.5%	65.7%	
Humidity	Low	41.6%	45.3%	
	OK	53.3%	46.7%	
	High	5.1%	8.0%	
Light	Low	3.7%	5.8%	
	OK	81.8%	83.9%	
	High	14.6%	10.2%	
Noise	Low	1.5%	0.0	
	OK	78.1%	82.5%	
	High	20.4%	17.5%	
Odour	No	47.4%	52.5%	
Temperature	Low	15.3%	8.0%	
	OK	56.2%	71.5%	0.003
	High	28.5%	20.4%	

* The statistical procedure utilized was paired categorical data analysis (catmod); p values are shown only when equal to or less than 0.05.

TABLE V
Measured Environmental Variables (Each N Approx 690)

		1989	1990	p*
Temperature °C	Median	22.5	22.0	
	Mean	22.7	22.0	0.0001
	Minimum	19.1	14.2	
	Maximum	26.8	25.1	
Relative Humidity	Median	17 %	20 %	
	Mean	19.7%	20.5%	
	Minimum	5 %	11 %	
	Maximum	56 %	51 %	
Particulates mg/m³	Median	0.009	0.009	
	Mean	0.023	0.014	
	Minimum Value = 0	3.1%	1.6%	
	Minimum >0	0.001	0.001	
	Maximum	5.3	0.32	
Carbon Monoxide ppm	Mean	0.003	0.004	
	Minimum Value = 0	99.7%	99.9%	
	Maximum	1	3	
Carbon Dioxide ppm	Median	490	480	
	Mean	491	481	0.03
	Minimum	330	380	
	Maximum	710	650	
Volatile Organic Compounds mg/m³	Median	1.5	0.6	
	Mean	1.6	0.9	0.0007
	Minimum Value = 0	23.5%	27.6%	
	Minimum >0	0.01	0.45	
	Maximum	35.9	27.2	

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* Paired t tests were utilized for comparing the means across the two years; p values are shown only when equal to or less than 0.05.

DISCUSSION

Other findings suggest that the study population is a relatively typical one. Their frequency of symptoms occurring at home, along with the number of doctor visits and illness days per year are similar to males and females of comparable age in random homes,[17] and in another study of office building workers.[18] However, the proportion of current smokers in the study population (Table I) is lower than expected.* This result is not explained either by workers having stopped smoking in advance of the smoking ban, or by smokers tending to opt out of the study, but may represent the current reality among office workers since

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TABLE VI
Considerations of Bias[a]

	Repartic 1989	Dropout 1989	p[b]	Repartic 1990	Addition 1990	p
No. of Subjects	137	42		137	322	
Age	41.6	41.2	.	42.6	42.4	.
Female	60.6%	64.3%	.	60.6%	66.7%	.
Smoke						
Never	21.9%	28.6%		40.0%	44.5%	
Never+Passive	35.0%	22.6%		18.5%	16.5%	
Ex	10.2%	17.7%	.	22.2%	20.3%	.
Ex+Passive	20.4%	26.3%		6.7%	4.2%	
Current	12.4%	10.5%		12.6%	14.5%	
Other Cig/Day at Work	6.0	4.3	.	0.1	0.2	.
Saliv Cotinine	6.5	3.4	.		NA	
Work Years	6.3	5.4	.	7.4	8.3	.
Job Rank Low	48.9%	56.1%		48.2	60.5	0.02
Comfortable	80.3%	64.2%	0.04	74.5%	71.7%	.
Work Health Complaint[c]	19.7%	38.1%	0.02	21.9%	19.4%	.
Sum Symp						
Home	1.9	1.9	.	1.7	1.4	0.05
Work	4.0	4.5	.	3.5	3.8	.
Perceived Air Movement						
Low	56.9%	54.8%		57.7%	66.5%	.
OK	37.2%	26.2%	0.03	33.6%	26.1%	.
Fresh Air						
Low	74.5%	76.2%		70.8%	82.9%	
OK	25.6%	23.8	.	28.5%	16.8%	0.02
Light						
Low	3.7%	2.4%		5.8%	9.4%	
OK	81.8%	83.3%	.	83.9%	72.9%	0.04
Measured Humidity	20.4%	20.9%	.	20.0%	17.5%	0.0001

a Certain minor differences occur between columns 1 and 3 in this table and the data for the same groups shown in earlier tables. This is explained on the basis of occasional deletions of individual observations due to the use of paired analysis in Tables I - V.
b The groups within a given year are compared by t tests and chi-square analysis. Beyond the initial descriptive variables, those included are selected on the basis of showing a significant difference in any comparison.
c Percent of subjects who had lodged a work-related health complaint.

a similar frequency is found in the additional group of 322 subjects from the same buildings (Table VI).

The small decrease in questionnaire symptom reporting observed at the second survey (Table II) may be related to the introduction of the smoking ban, or may be a consequence of surveying the same population a second time. An unexplained reduction in symptom reporting also has been reported in two previous studies of re-examined populations.[13,14]

The main environmental impact of the smoking ban is a virtual disappearance of reported exposure to ETS at work (Table I). This is not accompanied by any change in the proportion of current smokers among the study participants (Table I), and contrasts with a 20 to 25% diminution of current smokers found following a smoking ban in two other studies,[5,6] but is similar to the 4% decrease reported in a third.[15] Our results may be related to the initially low frequency of current smokers (Table I).

The salivary cotinine levels measured in this study are consistent with smoking status, number of smoked cigarettes to which the subjects were exposed, and particulate levels (Table III and Results section). The level found among non- and ex-smokers is comparable to that reported in other studies, although the proportion of zero measurements is high[16] and the level among current smokers is lower than in some other studies.[17]

The combustion of tobacco is known to generate volatile organic compounds.[2] Accordingly, there is some credibility to the decreased level of ionizable substances found at the second survey (Table V). About 47% of the measured levels of these agents obtained in the first survey and 11% at the second, are above the level of 1.7 mg/m^3, which may produce irritant effects.[18] We found a significant decrease in the questionnaire reporting of eye irritation and headache at work in the second survey (Table II). Although a connection with the lower levels of volatile organic compounds is plausible, the alternative attribution of this decrease to a second administration of the questionnaire cannot be excluded.

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